THE EXPLOSIVES ENGINEER

REG. U. S. PAT. OFF.

Forerunner of Progress in Mining, Quarrying, Construction

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By A. PERRY MASON

Views and opinions expressed by the authors of articles in this publication are their own, and they do not necessarily represent those of the publisher.

As far back as 1912, E. W. Davis, a young professor in the mining department of the University of Minnesota, began working with taconite ore in a laboratory. He foresaw that the rich shipping ores in the Mesabi Range would become depleted and the harder-than-granite taconite ore would be the source of iron for the making of steel.

Developments through the years proved the professor to be right. The direct shipping ores are dwindling, and at a time when the need for steel has never been greater.

Taconite ore is one of the world's hardest rock formations. Only the most advanced methods and techniques in drilling holes for blasting and in the selection and use of the right combination of explosives can break taconite ore for profitable crushing and milling operations.

Reserve Mining Company is the pioneer in the mining and milling of taconite ore on the Mesabi Range. Owned equally by Armco Steel Corporation and Republic Steel Corporation, the company traces its origin to the beginning of iron-ore recovery in Minnesota.

Reserve's activities in the taconite field comprise a huge open-pit mine, a primary crushing plant, and a 300,000-ton-a-year processing plant at Babbitt, Minnesota; and a 47-mile standard-gauge railroad to Silver Bay, Minnesota, the site of a 3¾ million-ton-a-year plant, a harbor, and extensive shipping facilities.

The mineral formation in the mine at Babbitt is a deposit of magnetic taconite containing 25 to 30 per cent iron. The pit is 9 miles long, 2,800 ft. wide, and 175 ft. at the deepest point. The drilling of blast holes into the diamond-hard rock presented a serious problem. The introduction of jet-piercers solved that problem. These machines burn holes into the taconite at a rate as high as 40 ft. in an hour, as compared with 1 ft. an hour for conventional drilling rigs.

The drilling and blasting pattern was tailored to the job. After many experiments, a multiple-row double-V drilling pattern was adopted. The blast holes are loaded alternately with semigelatin dynamite, primed with an XC45 booster and plastic wire-countered Primacord,* and free-flowing TNT. The explosives loading ratio is 0.52 lb. per ton of taconite in place.

Primary crushing of the blasted material is done at the Babbitt plant, where Reserve operates the world's largest crusher. After primary crushing, the material travels the 47 miles to Silver Bay for final processing into pellets for use in Armco and Republic steel mills.

Lewis Nordyke's comprehensive article, beginning on page 6, describes in detail the operations of Reserve Mining Company in mining and milling taconite ore into pellets with an iron-ore content of 62.5 per cent.

* * *

The highlight of the second annual Golden Awards dinner of The Beavers, held on January 17 at the Biltmore Hotel in Los Angeles, was the presentation of the awards to 11 men prominent in the heavy-engineered construction industry west of the Mississippi.

Please turn to page 26.

* * *

In this issue, beginning on page 27, it is our privilege to reprint a prize-winning paper titled "The Use of Short-Period Delay Electric Blasting Caps in Underground Clay Mines," by A. Perry Mason.

The author delivered the paper to members and associates of The Refractories Institute of Pittsburgh, Pennsylvania, at the 1956 Annual Award Contest, and was awarded first prize.

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SUBSCRIPTION RATES: *United States and Canada*—One Year, $1.50; Single Copies, $.30. *Limited Subscriptions Only to Other Countries*—One Year, $2.50; Single Copies, $.50.

THE EXPLOSIVES ENGINEER, 612 DELAWARE TRUST BUILDING, WILMINGTON, DELAWARE. PRINTED IN UNITED STATES OF AMERICA.

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VOL. 35 NO. 1 JANUARY-FEBRUARY, 1957

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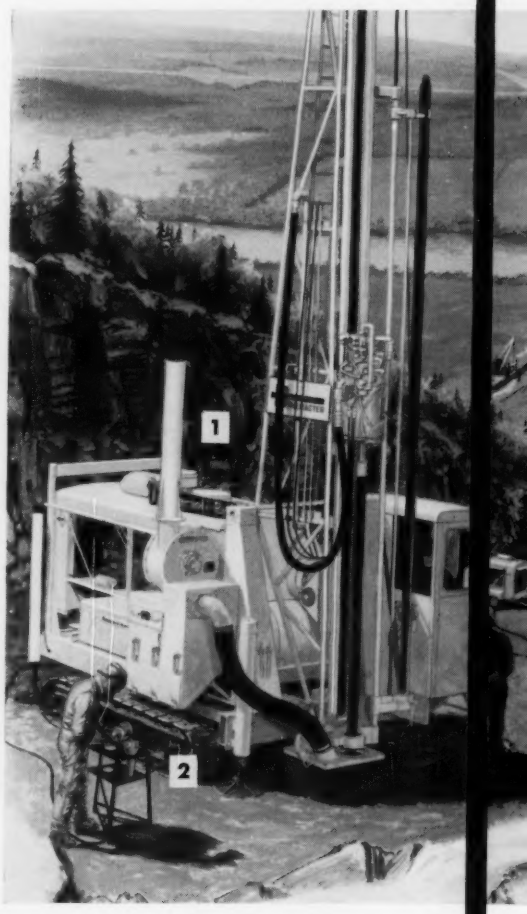

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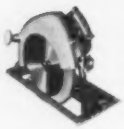
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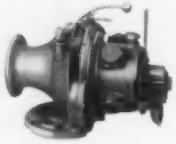
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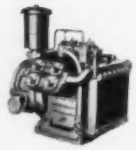
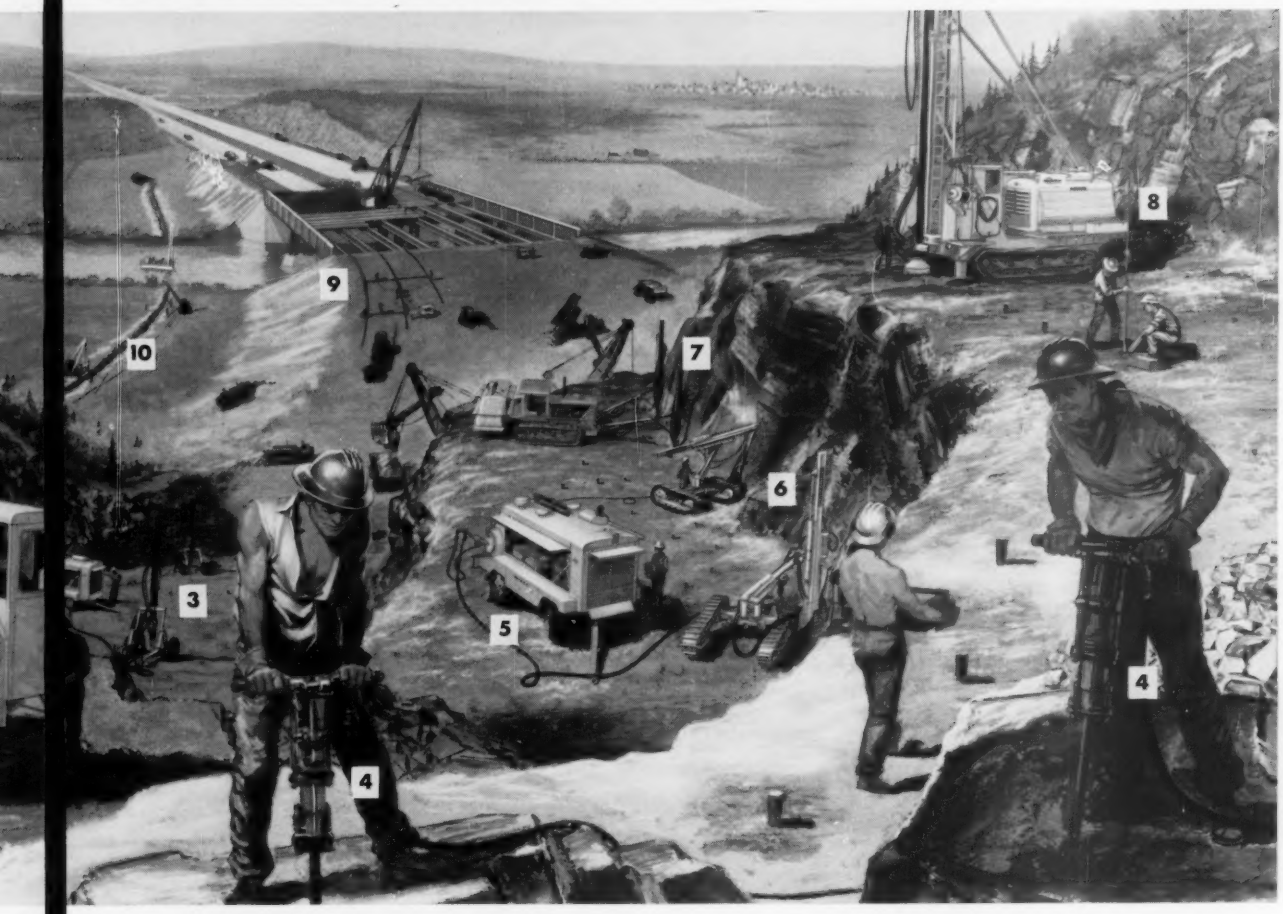
Spot-Air Compressors


Stationary Compressors

Motorpumps

Highway Construction Picture



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ORSON A. ROCKWELL

Orson A. Rockwell

VICE PRESIDENT AND GENERAL MANAGER

MINING AND SMELTING DIVISION

THE EAGLE-PICHER COMPANY

A Biography

In reviewing the careers of successful mining executives, the records show them to be hard-hitting, fair-minded individuals who played important parts in the development of the mineral industry. High in the list of our modern leaders in the mining profession is Orson A. Rockwell, vice president of The Eagle-Picher Company and general manager of its Mining and Smelting Division.

"Rocky," as he is known to his friends and associates, was born in Grand Rapids, Michigan, on April 29, 1906, the son of Ralph C. and Margaret C. (Salt) Rockwell. He received his elementary education at the Burton School in Grand Rapids and the Grand Rapids South High School.

When he was fourteen, Rocky took a job as errand boy for James Bayne Company, local commercial photographers, during after-school hours and summer vacation months. He continued in this job during his four years in high school.

Upon graduation from high school in 1924, Rocky went to work as a laboratory assistant in the gypsum and plasterboard operation of Certain-Teed Products Company's plant located in Grand Rapids, Michigan.

After a year with Certain-Teed, he left the company to enroll at Grand Rapids Junior College and was graduated with the class of 1927. He then matriculated at Michigan College of Mining and Technology at Houghton, Michigan; two years later he completed his studies and was awarded Bachelor of Science and Engineer of Mines degrees.

Soon after graduating from college, Rocky began his career as a mining engineer with Montreal Mining Company at Montreal, Wisconsin. This company operated one of the largest underground iron-ore mines in the Lake Superior District. His duties consisted primarily of development and production work.

Seven years later, he became associated with Colorado Fuel & Iron Company at its iron mine in Sunrise, Wyoming. The mine was the first to use the block-caving method for the extraction of iron ore.

In 1943, Rocky joined Calumet & Hecla, Inc., as an engineer in its Calumet Division. Subsequently, he was advanced to the positions of mine superintendent, assistant general manager, general manager, and vice president. The company's activities included eight mines, a mill, a smelter, leaching and chemical plants, a foundry, and shops.

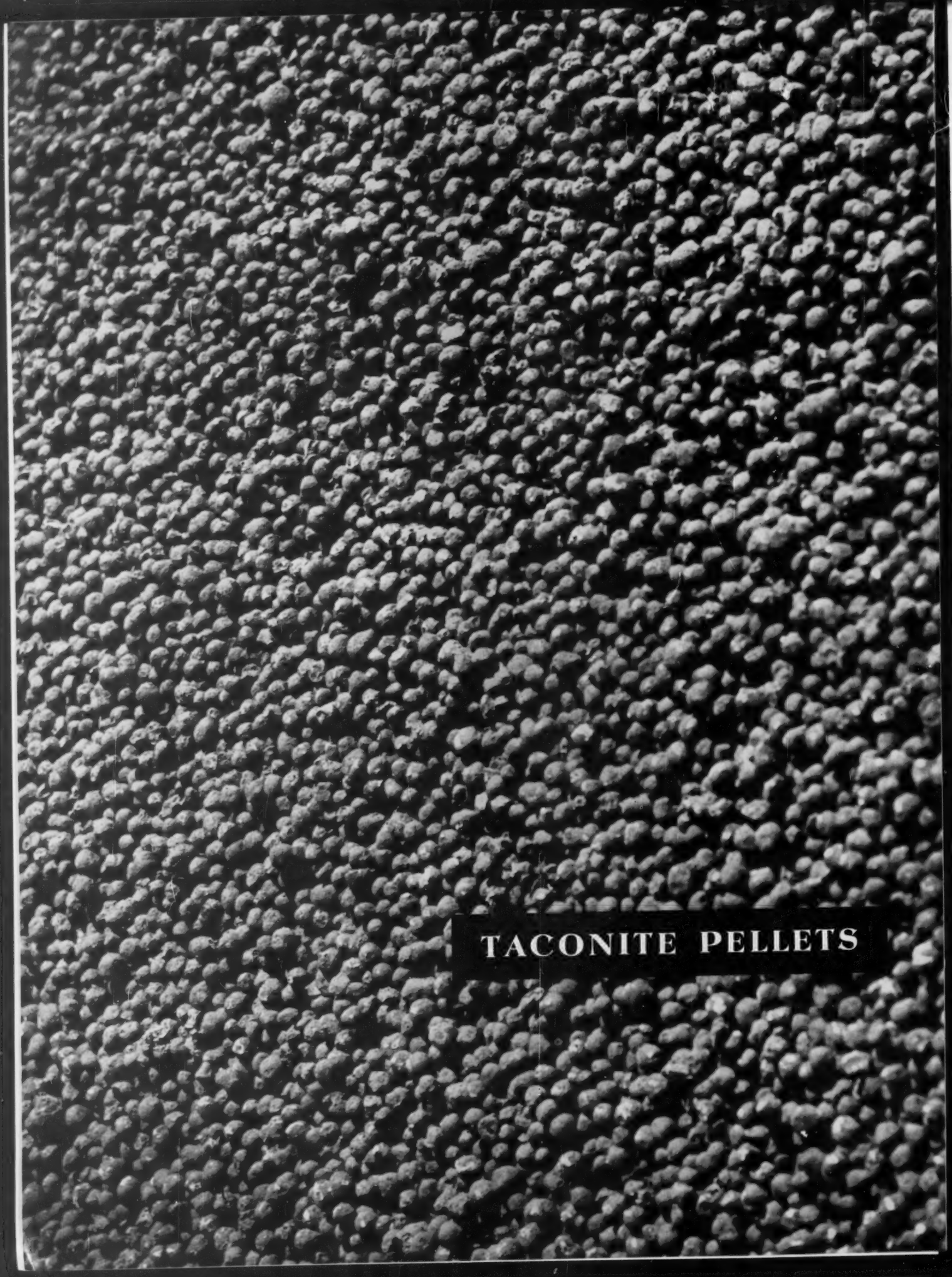
On April 1, 1954, Rocky began his association with The Eagle-Picher Company as a vice president and the general manager of its Mining and Smelting Division, the positions he holds today.

With its principal mining activities centered in the Tri-State District of Missouri, Kansas, and Oklahoma, Eagle-Picher is a well-diversified organization: four mines and three mills in the Illinois-Wisconsin zinc and lead fields; a mine and a mill near Tucson, Arizona; two mines and a mill in Mexico; and plants at key locations throughout the United States that manufacture a wide variety of products. Its operations in the Tri-State District include seventeen mines, a concentrator, and a smelter.

Mr. Rockwell is a director of the American Mining Congress, American Zinc Institute, and the Oklahoma Medical Research Foundation. He is a member of the National Committee on Mineral Resources of the United States Chamber of Commerce. He also holds memberships in the University Club of Chicago; Twin Hills Country Club of Joplin, Missouri; and the Miami Country Club. His fraternal and civic affiliations include the Masons, the Lions Club, the Elks, and the Miami Chamber of Commerce.

Orson A. Rockwell married Kathleen E. Richards on February 28, 1930, in Houghton, Michigan. They have two children: Nancy J. Rockwell Griner and Don A. Rockwell. The family home address is 1800 Rockdale Boulevard, Miami, Oklahoma.

When opportunity permits, Rocky finds relaxation from his varied responsibilities in playing golf with his friends and associates on nearby fairways and greens, and in the enjoyment of classical music with his family.


TACONITE PELLETS

TACONITE

Reserve Mining Company's activities in mining and milling taconite at Babbitt and Silver Bay, Minnesota, highlight the beginning of a new era in iron-ore production

LEWIS NORDYKE*

On the wild-wooded north shore of Lake Superior 55 miles out of Duluth is the brand-new town of Silver Bay, population 3,500. It is as sparkling a place up there in a cove of the birch-dotted hills as its name implies. Running out of there toward the northwest is a new railroad. It goes for 47 miles, almost to the edge of northern Minnesota's colorful canoe country and stops at Babbitt, population 2,000, another brand-new fast-growing town on the famed Mesabi Iron Range.

All this new scenery is only the prelude to an exciting story of the ingenuity and skills of American industry. It all came into being through the development of taconite as a source of rich iron ore.

Taconite itself is not new. It is an iron-bearing slate or chert which occurs in the form of a compact siliceous rock. The iron content is so fine that nearly all the particles are 20 mesh. This taconite, containing magnetic iron mineral, was probably one of the first things discovered on the Mesabi Range. But it was by no means bonanza stuff. Extremely hard and with an iron content of only 25 per cent, it couldn't be charged direct into a blast furnace for turning out pig iron. Besides, there was plenty of rich iron ore, comparatively soft material that could be readily blasted in pits, excavated, and shipped direct to blast furnaces. So, only a few people, among them E. W. Davis, a professor at the University of Minnesota, indicated much interest in taconite. In a long, hard fight, involving politics, research, and costly experimentation, Professor Davis kept insisting that one day the rich shipping ores would become depleted and taconite would become American industry's main source of iron ore for steel making.

Prophesy Becomes Reality

Developments have proved that the professor was right. Direct shipping ores are dwindling into short reserves. The need for steel for our modern way of life and national defense is greater than ever before. The almost inexhaustible supply of taconite, the once-rejected rock, is now coming in mighty handy. The professor, now living comfortably in retirement at Silver Bay, has seen his baby develop into a half-billion-dollar he-man.

This prophesy has been slowly coming to reality through the past 40 years and two steel-consuming wars. It has undergone patient research in mining and milling. It has also depended on vastly new thinking as to techniques in drilling and blasting.

Taconite is one of the world's hardest rocks. Its iron content is sprinkled through it about like pepper in pork sausage. Conventional drills couldn't make effective headway in it, and along came the development of jet-piercers to burn into the stuff. Only the most advanced methods and techniques in blasting with explosives can break taconite for profitable crushing and milling operations. Expensive beneficiation is required, and, in the milling process, the ore has to be ground so fine that it would blow out at the stacks if charged into a blast furnace. Therefore, it requires the additional process of pelletizing into hard chunks about the size and shape of a

*2809 Lipscomb Street
Amarillo, Texas

TACONITE OUTCROP: This is a close look at one of the many outcroppings of taconite ore on Reserve Mining Company's property at Babbitt, Minnesota. The ore, containing 25 per cent iron, is almost as hard as a diamond.

plump peach seed to make it economically usable in the manufacture of steel products.

Perhaps it should be pointed out here that there is a great difference between mining and processing taconite and high-grade ore. The mining of taconite formations is difficult enough, because of the extreme hardness of the rock. But, it is the processing of taconite that makes the costs mount up. The milling requires three times as many jobs per ton as do the direct shipping ores. Moreover, extensive plants and equipment are required, not to mention continuing research and experimentation. As a rule, direct shipping ores have required a capital investment of $3 to $4 per ton of annual capacity. To produce taconite pellets, the investment in mine and plant facilities totals $30 to $40 per ton of annual capacity.

Problems Solved One by One

However, a combination of industry, mining, milling, and explosives engineers has faced up to all the problems and solved them one by one. Taconite is now an established and important part of the steel industry. Again the Mesabi Range in the land of many lakes is booming.

Reserve Mining Company, which, through various changes in ownership, can trace its history back to the beginning of iron-ore recovery in Minnesota, is a pioneer in the mining and milling of taconite. The company is owned equally by Armco Steel Corporation of Middletown, Ohio, and Republic Steel Corporation of Cleveland, Ohio. The two companies use in their steel mills the total output of the Minnesota operation comprising a tremendous open-pit mine, a primary crushing plant, and a 300,000-ton-per-year processing plant at Babbitt, a 47-mile railroad to Silver Bay, and a 3¾ million-ton-per-year plant, harbor, and shipping facilities there.

All of this has taken place in the past few years. It was not until the early part of 1956 that the mammoth mill at Silver Bay was brought into full production. However, events leading to the significant developments in the economical mining and milling of taconite have been shaping up for a long time. The grandpappy of Reserve Mining Company was born back in 1875 when the original Mesaba Iron Company was organized and acquired

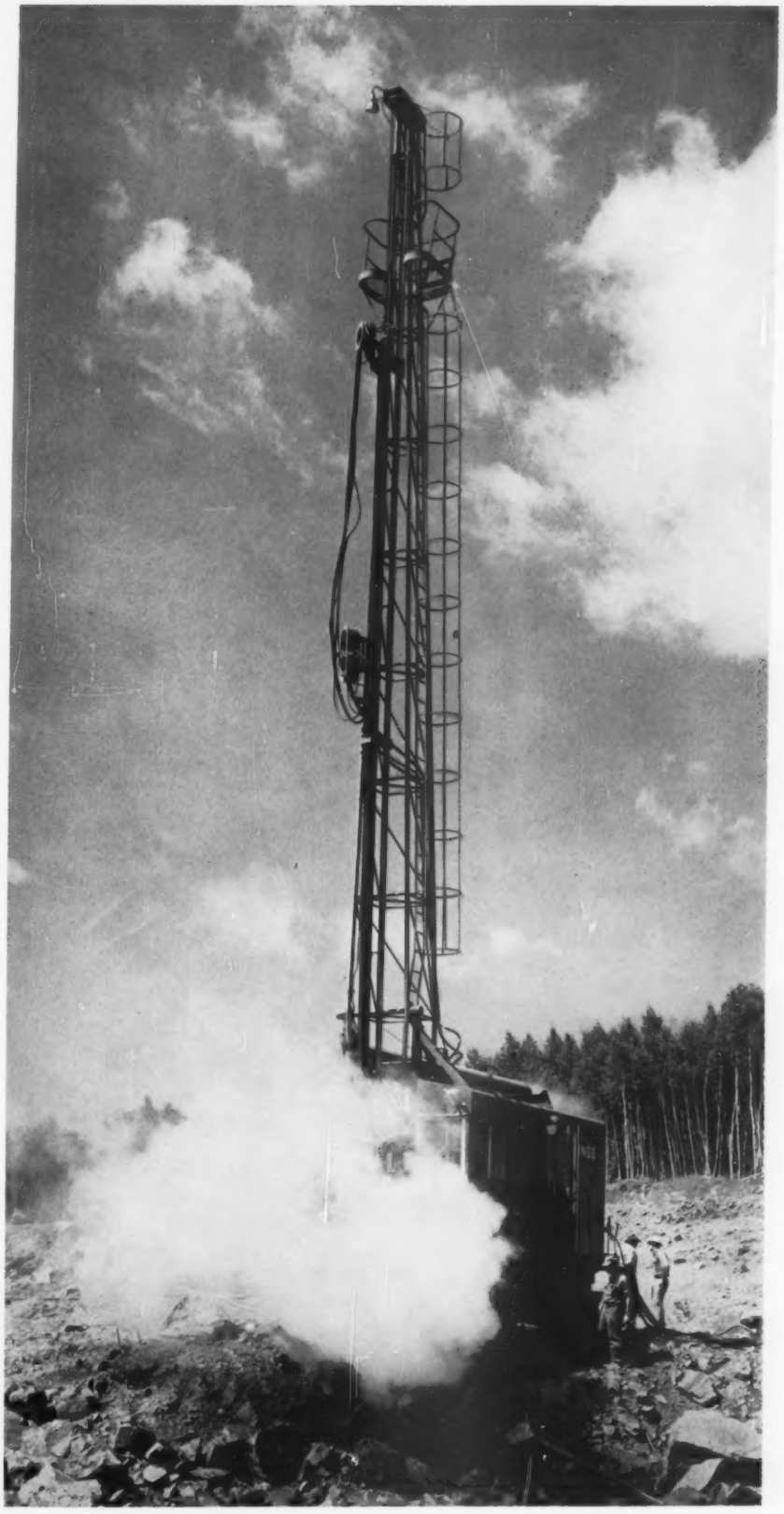
much of the taconite properties now under lease to Reserve. Thirty years later, two new companies acquired Mesaba Iron Company and added to the mineral-bearing lands. Eventually, in 1916, this enterprise became the Dunka-Mesabi-Security Company.

At about that time, D. C. Jackling, whose fame as a copper mine operator in Utah and Nevada had become widespread, came to the Iron Range. He became a driving force in the new company, which added more property, including land for a townsite and a plant at Babbitt. In 1916, it built an experimental plant in Duluth to process taconite. Three years later, the Mesabi Iron Company was formed and it took over all the properties and processes. It decided to mine and mill at Babbitt, and a plant was completed in July of 1922. The enterprise was a failure because it was about 30 years too early. The material processed from taconite simply could not compete with the direct shipping ores, which were plentiful everywhere. So, after turning out 157,570 tons of sinter with about 62 per cent iron, the plant was closed and little Babbitt died as dead as a door nail.

Big Things Began to Happen

From then until 1929, taconite was little more than a topic of discussion among iron men and the subject of an occasional learned paper on the possible future of the hard, dense rock. It was then that the late Joseph H. Frantz of Armco Steel Corporation and the late R. C. Allen of Oglebay Norton & Company decided to make a more thorough investigation of the potential of taconite. In 1937, Allen negotiated for a lease assignment of the properties of the Mesabi Iron Company. Two years later, on March 24, 1939, Reserve Mining Company was organized. Eventually, in December of 1951, Armco and Republic became equal owners of Reserve. By that time things were happening in a big way, mainly because of the single-handed activities of Professor Davis, who was director of Mines Experiment Station of the University of Minnesota.

As early as 1912, Davis, a young engineer, had worked with taconite in a laboratory. At that time, he envisioned the harder-than-granite rock as



THE JET-PIERCER: Here's one of Reserve's jet-piercers burning a blast hole into the taconite ore from a bench in the pit at Babbitt. These machines make possible the economical recovery of the iron in the taconite.

the future source of iron and steel. As the mighty maw of steel mills gobbled the direct shipping ores, Davis talked taconite. He endangered his job at the university by covering the state and preaching that taconite would eventually be a big thing in Minnesota, the Great Lakes Region (which has furnished about 35 per cent of the world's steel), and the nation. He campaigned for state tax relief on taconite so that use of the ore could be promoted. Finally, in 1941, this fight was successful, when the Minnesota Legislature passed a law which limits the amount of ad valorem tax that can be assessed against taconite and its mining and processing facilities. A tax is levied on production rather than on reserves and facilities.

The property at Babbitt was put in stand-by condition. Obsolete equipment and material were junked. Reserve personnel, in collaboration with Professor Davis and his staff, began to seriously study processing methods. In 1941-42, Davis and his staff developed the pelletizing method of agglomeration. In 1948, the pellets were tested in an experimental blast furnace at the Mines Experiment Station, and the first iron made exclusively from taconite was produced. It looked good. Additional experiments, quite successful, were made at Armco's works in Ashland, Kentucky. By 1949, the decision to mine and mill taconite was made, and things began to move in a hurry.

Although this development had been coming gradually since 1875, and more especially since 1912, Reserve

THE BABBITT PIT: After primary blasts are fired in a bench in the open-pit mine at Babbitt, the ore is excavated and loaded into 45-ton side-dump trucks by electric shovels with 5-cu. yd. dippers. A jet-piercer is at work at top background.

Mining had to start from scratch.

There was almost nothing at Babbitt except the ore and the old buildings. Mining was started. The plant was remade and put into operation in 1952. It has a rated annual capacity of 300,000 tons.

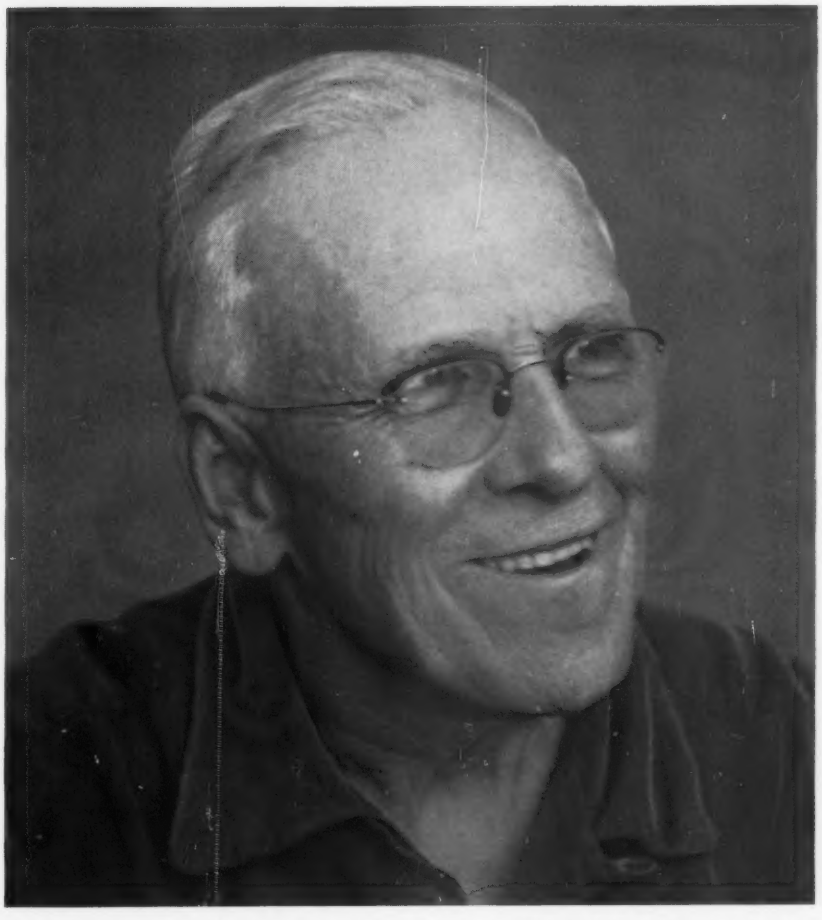
Efficiency the Watchword

Since the mining and milling of taconite are much more expensive than the handling of direct shipping ores, efficiency in operations had to be the watchword. Tremendous amounts of water are required for milling and pelletizing. Therefore, Reserve decided to erect its principal fine-crushing and concentrating plant on Lake Superior. This meant that several big things had to be accomplished quickly.

The company had to build a modern town adjacent to the mine site and the small concentrator. The new and complete town of Babbitt rose from a potato field. The standard-gauge railroad from the mine to the plant site on Lake Superior had to be surveyed and constructed. There was nothing at the plant site except rock and forest land in a virtually uninhabited wilderness. Silver Bay came into being there almost overnight. Construction work on the plant at Silver Bay started in July of 1951. The project required the moving of more than 9,000,000 cu. yd. of rock, dirt, mud, and muskeg. More than 130,000 cu. yd. of concrete were poured. The job also required 25,616 tons of structural steel, 7,000 tons of reinforcing steel, and nearly 300,000 lin. ft. of steel piling. The plant was completed in the summer of 1955 and the first pellets were shipped in the fall. The pellets were rich iron ore – 64 per cent iron. The Silver Bay plant was named the E. W. Davis Works in honor of the professor who now is often known as "Mr. Taconite." He is a consultant for Reserve.

The bill for all this development and construction came to around $190,000,000. In January of 1953, to raise capital for the project, Reserve sold an issue of $148,000,000 first mortgage 4½ per cent bonds to a group of life insurance companies. The remainder of the required funds was supplied by Armco and Republic.

In the middle of 1951, clearing of timber and stripping of glacial overburden were started. In the summer of 1952, the mine was opened and the main haulage road to the primary crusher was built and began functioning immediately.

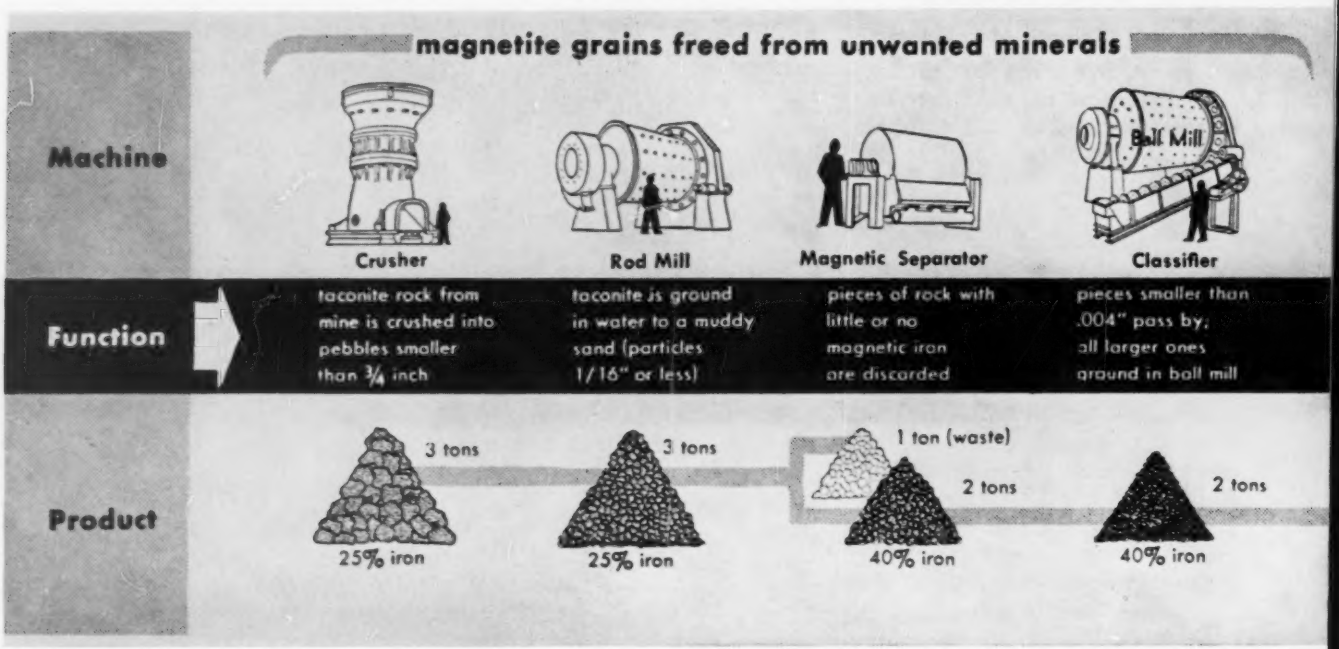


"MR. TACONITE": Professor E. W. Davis started to work with taconite in a laboratory in 1912. His persistent efforts through the years were responsible in large measure for the development of techniques in use today for the economical mining and milling of taconite ore.

Reserve's Taconite Deposit

Reserve's mineral property is a deposit of magnetic taconite containing 25 to 30 per cent iron in the form of tiny particles of ore disseminated throughout the rock. The mine is located in St. Louis County at the eastern end of the Mesabi Range. It is about 9 miles long, 2,800 ft. wide, and 175 ft. deep at the thickest point. The deposit is known to contain 1,400,000,000 tons of magnetic taconite. Since it takes 3 tons of taconite to produce 1 ton of pellets, the deposit represents close to one-half billion tons of high-grade ore. There is very little overburden covering the rock formation and outcroppings of taconite are frequent.

As everyone realized from past experience with the diamond-hard rock, blasting the ore was, and is, a tremendous job. In the first place, conventional drills could drill blast holes at a rate of about 1 ft. an hour, and, usually, four changes of bits were necessary. There had to be a faster, more economical way of drilling blast holes. Linde Aircraft Products Company came through with a jet-piercer that burns holes in the rock. It works somewhat on the same principle as American Indians used in breaking large rocks and chipping out arrowheads and spear points – heat by fire and douse with cold water. The jet-piercer is a complicated flame-thrower, burning oxygen and kerosene, or fuel oil. It creates heat of 4300 degrees F. The flame strikes the rock and the in-



STEP BY STEP: This graphic presentation shows Reserve Mining Company's met

tense heat causes a thin surface layer to expand and break away. The action of the jet blows the spalled rock out of the path of the flame and exposes fresh surface to the red-hot attack. Water poured into the hole serves as a coolant; it quenches and embrittles the fused material and preserves the combustion chamber and nozzle. The water is converted into steam which ejects the cuttings from the hole. Combustion of the liquid petroleum with gaseous oxygen in the burner chamber at a pressure of 100 to 200 p.s.i produces the high-temperature jets. The jet-piercing machine, with a 50-ft. derrick mounted on a crawler-type tractor, weighs 77,000 lb. The machine cuts through the taconite at a rate as high as 40 ft. an hour. The rig can be moved from one hole to the next and leveled up in 15 minutes. Reserve has five jet-piercer machines in the mine.

After clearing and stripping, the first operation was in a long development cut. This was done so that box-type cuts could be made later to the left and the right of the development cut.

Drilling and Blasting

Benches are uneven, owing to the rough and variable terrain; they average about 35 ft. The jet-piercer is reckoned to drill a hole 6½ in. minimum diameter. Actually, the hole drilled is about 8½ in. Their depths range from 15 to 50 ft., depending upon height of benches. Each hole is chambered, or sprung, the enlargement measuring about 5 ft. deep and 13 in. in diameter at the bottom. This is done by suspending the piercer in the area to be chambered and the jet enlarges the bottom of the hole.

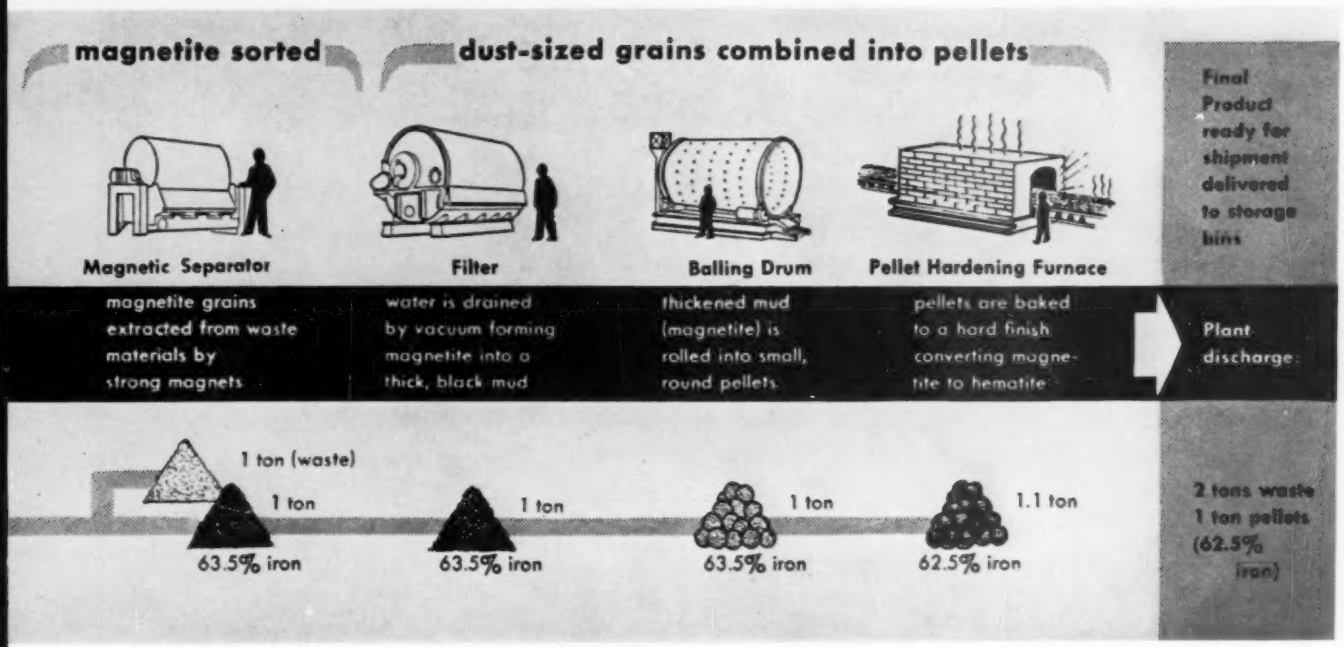
Holes are loaded with explosives on a ratio of 0.52 lb. of dynamite to each ton of material in the solid.

The blasting pattern had to be engineered. Fragmentation of the ore in primary blasts had to be sufficient for uninterrupted handling by the primary crusher. Because of the higher cost of processing taconite, in comparison with direct shipping ores, steps had to be taken to avoid the use of excessive amounts of explosives.

Reserve's management and supervisory personnel believe in having the main rock-breaking job done in the pit instead of in the crusher. They worked closely with explosives sales engineers in determining an effective drilling and blasting pattern. At first, two rows of holes 19 ft. apart were used. Results were not entirely satisfactory. Then, three rows were tried, and, finally, a single row. Breakage was poor, especially near the surface, and too much secondary blasting was necessary. Also, there were large chunks of the highly abrasive ore in the muck pile that were hard on shovels, trucks, and crushing equipment.

Finally, a method was developed that called for a multiple-row double-V pattern, with as many as 23 rows of holes in a single blast. At the same time, the loading and priming of explosives charges to fit the new drill pattern were given careful study. In recent months, the breakage has improved to the point where wear and tear on equipment has been greatly reduced. For example, the concave on the coarse crusher will now handle 200,000 more tons without a change than it could before the drilling and blasting were carefully engineered.

The multiple-row drilling pattern for a typical primary blast calls for 10 to 12 rows of holes spaced on 19-ft. centers, with the holes in each row 19 to 20 ft. apart. All holes are drilled from the top of a bench to a depth at least 3 ft. below the grade of the bench. This provides for breakage of the rock at the toe, or bottom of the bench. This pattern has also minimized backbreak, thus reducing fractured ore in areas to be drilled for succeeding blasts. As all rock men know,


magnetite sorted
dust-sized grains combined into pellets
Final Product ready for shipment delivered to storage bins
Magnetic Separator
magnetite grains extracted from waste materials by strong magnets
Filter
water is drained by vacuum forming magnetite into a thick, black mud
Balling Drum
thickened mud (magnetite) is rolled into small, round pellets
Pellet Hardening Furnace
pellets are baked to a hard finish converting magnetite to hematite
Plant discharge
1 ton (waste)
1 ton
63.5% iron
1 ton
63.5% iron
1 ton
63.5% iron
1.1 ton
62.5% iron
2 tons waste
1 ton pellets (62.5% iron)

methods of processing crushed taconite ore into pellets containing 62.5 per cent iron.

fractured formations slow down drilling speed considerably.

Loading the Explosives

In loading charges of explosives into a blast hole, a 6 by 24-in. 23G container of EP 152 semigelatin, primed with an XC45 booster and plastic wire-countered Primacord,* is lowered to the bottom. Then 50 lb. of EP 158 pelletized TNT are poured into the hole. The alternate loading of cartridges of dynamite and free-flowing TNT is continued until the hole is filled almost to the top where 5-in.-diameter cartridges replace the 6-in.-diameter ones. The explosives loading factor is based on a ratio of 0.52 lb. per ton of taconite in place.

When the column of explosives has been raised to 8 or 9 ft. of the top of the hole, a 5-in. by 25-lb. primer cartridge is loaded. Then 2 ft. of stemming is placed, which brings the stemming to 6 ft. from the surface, where another primer charge of 6 lb. of dynamite is loaded. The hole is then stemmed up to 3 ft. of the collar, after which a final 6-lb. primer charge is loaded. Then the hole is filled with stemming to the collar.

As additional assurance in getting good all-over breakage throughout the blast area, 1¾-in.-diameter holes are drilled from the top of the bench to a depth of about 5 ft., on an irregular spacing pattern that averages about 6-ft. centers. These are called satellite holes. Drilling is done with an arm drill mounted on a tractor, which also accommodates a 125-c.f.m. compressor. The drill is equipped with 6-ft. steel and carbide insert bits. The holes are loaded with free-flowing EP 158 explosives primed with Primacord. The loaded holes are hooked into the trunk lines of Primacord. In making these connections, short-period delay electric blasting caps are used in about one-quarter of the loaded holes. A blasting cap is tied to the Primacord which connects all the big and little holes on top. After men and equipment have been moved from the pit, the blast is fired with safety fuse and a blasting cap.

From 50 to 90 tons of explosives are used in each of these big blasts. Results average from 250,000 to 300,000 tons of ore. About five blasts per month keep the shovels busy.

This pattern of drilling and blasting has greatly reduced the height of the muck pile and minimized secondary blasting. For awhile, Reserve used a drop ball for breaking the bigger boulders, but abandoned the practice because it was too slow, costly, and hazardous. Now two types of secondary blasting are used, bulldozing and drilling. In bulldozing, which is mud-capping without the capping, 60 per cent high pressure gelatin is placed on top of the boulders and fired with blasting caps and Primacord. Some big boulders are drilled with a tractor-mounted arm drill. The 1½-in. holes are usually 2 ft. deep. They are loaded with 1¼ by 8-in. cartridges of Gelamite® 1, and fired with blasting caps and Primacord.

As much as 1,990,000 tons of ore have been blasted in one month in the Reserve mine. Results in recent months have been highly satisfactory, with fragmentation better than had been anticipated. The company uses about 8,500,000 lb. of explosives a year for primary blasting. Without the effective use of explosives, taconite could not be mined profitably.

Crushing Taconite

Reserve installed near the mine the world's largest rock crusher, a 60-in. gyratory which can take care of boulders as large as a cubic yard. The crusher weighs 1,250,000 lb. It is powered by two 500-hp. motors. The wide pit for the crushing plant, 80 ft. in diameter, was sunk in solid rock to a

*Reg. U. S. Pat. Off.
by The Ensign-Bickford Company

CRUSHING-PLANT FOUNDATION: In preparing the foundation for Reserve's crushing plant at Babbitt, a pit 80 ft. wide and 170 ft. deep had to be drilled, blasted, and excavated in solid rock formations.

depth of 170 ft., requiring the blasting and removal of 20,000 cu. yd. of rock. The opening of the crusher is much larger at the top than at the bottom. The top portion of the concave is the place that catches the big ones, while the smaller material falls through the larger opening and is crushed by the bottom section. With the improved fragmentation of the rock in the pit, the management hopes to be able to reduce the top opening of the primary crusher so the crushing of smaller material can start nearer the top. This would give more even distribution to the crushing surface.

The blasted material is excavated with 5-cu. yd. electric-powered shovels. The big shovels are capable of handling 7-cu. yd. dippers. The smaller size ones are used because any piece of rock a 5-cu. yd. dipper will load will go through the primary crusher. The shovels load into 45-ton, side-dump trailer trucks that haul to the crushing plant near the mine. The mine is equipped with seven shovels, five in use and two for spares, and 23 trucks, with 17 used per shift. The mine and the crushing plant, also the mill at Babbitt, work 20 shifts each week, with one shift taking care of repairs.

In addition to the 60-in. gyratory

WORLD'S LARGEST CRUSHER: Near the mine, Reserve installed the world's largest coarse crusher, a 60-in. gyratory that can handle boulders as large as a cubic yard. It weighs 1,250,000 lb. and is powered by two 500-hp. motors.

crusher, which reduces the material to a minus 8½ in., the crushing plant has four 30-in. gyratory crushers, three in use and one as a stand-by. These crushers reduce the rock to a minus 3 in. The big crusher has a capacity of 3,500 long tons an hour; the 30-in. secondary crushers have a combined rate of 3,000 tons per hour.

After the material is crushed, it goes to the bottom of the deep pit to a conveyor, a rubber belt in which steel cable is embedded. It operates at 120,000 lb. of working tension — strong enough to hoist a locomotive with loaded tender. It hauls the crushed taconite 1,000 ft. while raising it 280 ft., accommodating 3,360 tons an hour. The heavy conveyor, 60 in. wide and 1,000 ft. long, carries the minus 3-in. taconite to loading bins at a rate of 3,000 tons an hour. The two bins, 40

FROM MINE TO CRUSHER: Upon the arrival of a truckload of blasted ore from the mine at the big crusher, one side of the truck is lifted with a hook and its contents roll over into the opening of the crusher.

ft. in diameter and 150 ft. high, have a capacity of 9,800 tons. Material going to the concentrator at Babbitt is hauled from the bins to the plant. However, most of it is loaded on railroad cars of 85-long-ton capacity for the 47-mile trip to Silver Bay. Loading at the bins is at the rate of one car every two minutes. A train hauls 110 cars and makes six trips daily.

Diesel-electric locomotives move the trains over the 140-lb. steel rails, the heaviest made.

Upon arrival at the E. W. Davis Works at Silver Bay, the cars are dumped into the fine-crushing plant by a rotary dumper without being uncoupled. This is the only dumper ever built that handles standard-gauge railroad cars in this way. Crushing there is in two stages to about ¾ in., and then the material is conveyed into rod mills, where water is added, and the ore is ground into particles about the size of coarse sand.

Next it goes through the cobbers, or magnetic separators, which pick up the magnetic iron and discard the other material, mostly silica. The recovered material goes into the ball mills where it is ground to about the texture of flour, and then on to another series of magnetic separators which remove more tailings. The final process of concentration takes place in the hydroseparator in which the silica is removed by washing.

Pelletizing

The iron at this stage is very fine and as black as jet. It is rich in iron ore – 64 per cent – but is in no condition for hauling or blast furnace. So pelletizing is necessary. This is done in a revolving drum by rolling and rerolling the wet concentrate, to which bentonite has been added. As particles roll down the side of the drum they gather with other particles. A continuation of this action forms the pellets, in much the same manner as a snowball is formed. The pellets are coated with finely ground coal and dried in a furnace at 2400 degrees F. Thus, they are hardened and can stand the jar of handling and hauling. The E. W. Davis Works has an annual rated capacity of 3,750,000 tons of pellets.

From the pelletizing plant, the ore goes into stockpile or into five concrete bins 45 ft. in diameter and 80 ft. high, each with a capacity of 6,000 long tons. These are on the edge of the harbor. Ore boats nosing into the harbor are loaded by two movable loaders. Each houses a 60-in. shuttle conveyor with a capacity of 3,550 long tons per hour. Each has a boom section which can extend out 40 ft. from the dock.

From beginning to end – from extremely hard rock to pellet – the Reserve operation comes close to being superlative in every degree. It is almost impossible to realize that so much headway has been made in so short a time, even after you have seen it.

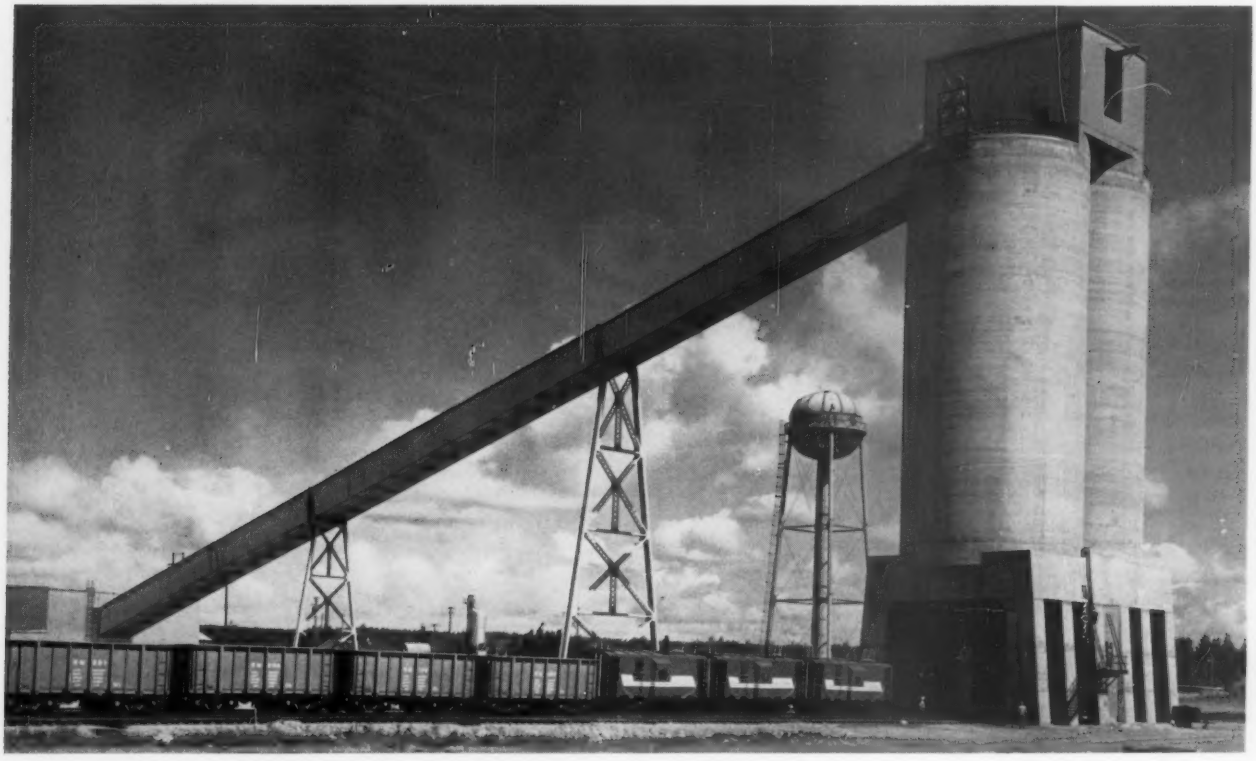
The building of the harbor was a major undertaking. It is formed by two breakwaters that extend from the shore to two small islands, Beaver and Pellet. The quay wall is 2,500 ft. long.

The Beaver Island Breakwater

The Beaver Island breakwater is

BELT CONVEYOR: After the taconite has been reduced in the crushing plant to minus 3-in. sizes, it is moved on a conveyor belt 5-ft. wide and 1,000 ft. long from 167 ft. below the ground to 125 ft. above the ground.

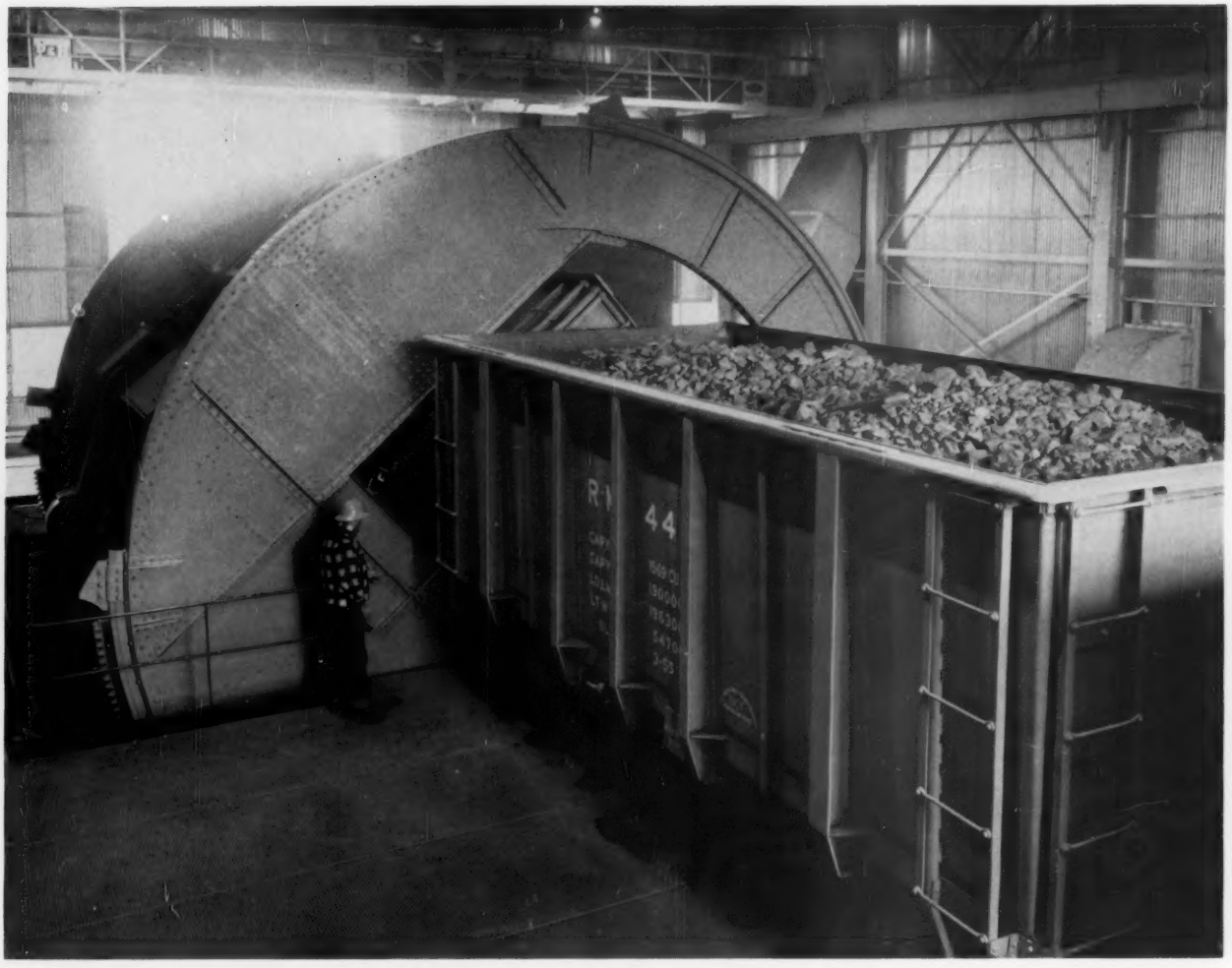
THE BABBITT PLANT: In 1952, the plant at Babbitt was remade and put into operation. Material going to the concentrator is hauled from bins to the plant. The rated annual capacity of the Babbitt plant is 300,000 tons of iron-ore pellets.



STORAGE BINS: Crushed taconite is stored in bins at the Babbitt plant. Most of it is shipped in railroad cars to the processing plant at Silver Bay. The bins are 125 ft. high and have a combined capacity of 10,000 tons.

RESERVE'S 47-MILE RAILROAD: Reserve had to build a standard-gauge railroad with 140-lb. steel rails to haul 110 cars loaded with crushed taconite from Babbitt to Silver Bay. Six of these trips are made each day.

AT SILVER BAY: This view of the E. W. Davis Works at Silver Bay shows the fine-crushing plant at right, the concentrator beyond the highway, the pelletizing building in right background, and the 50,000-kw. power plant at left.



ROTARY DUMPER: The car dumper at Silver Bay unloads a car of taconite into the fine-crushing plant without the car's being uncoupled from other cars in the train. It is the only installation of its kind in use today.

1,800 ft. long. It took more than a million cu. yd. of rock to build it. The breakwater is some 14 ft. above the surface of the water. Out in the lake where the depth of the water reaches 110 ft., the base of the breakwater is some 350 ft. wide. Dump trucks hauling out material for its construction were turned on a turntable. The harbor required the dredging of 164,000 cu. yd. from the lake bottom. Reserve company's engineers make use of everything; they figured a way to gradually force the tailings, as they go into the lake, toward the breakwater to add support to it.

Many things had to be given careful consideration in the creation of this industrial giant, for example, the weather. It gets cold in Minnesota in the winter months. However, operations were planned for a year-around project. Antifreezing chemicals are used in the crusher plant at Babbitt, also at Silver Bay, to prevent delays because of frozen ores. At the Silver Bay crushing plant, a boiler was installed to supply steam for steaming cars that may contain frozen ore. When the lake shipping season ends with the coming of the icy months, mining and milling continue, and the pellets are stockpiled.

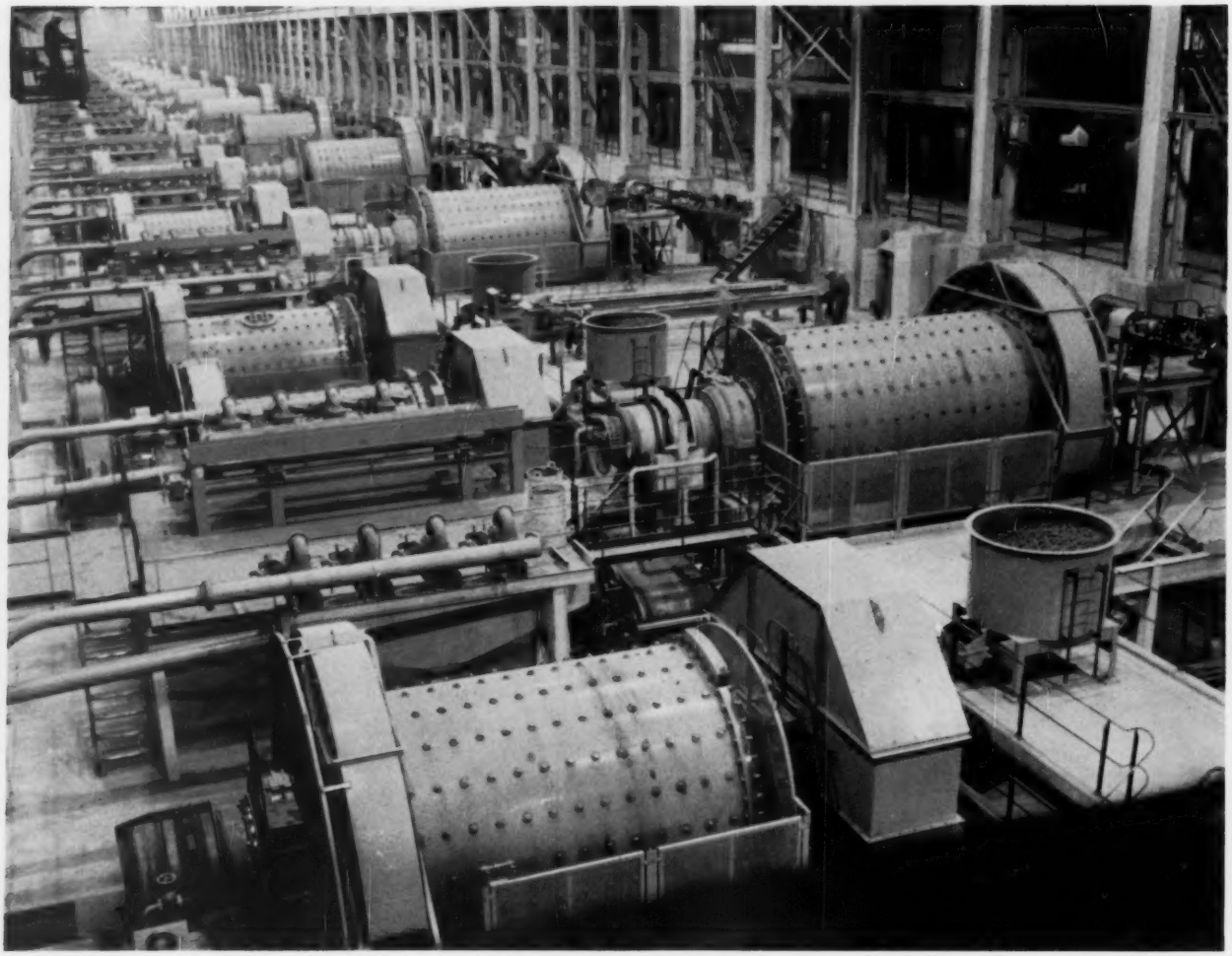
As indicated previously, the E. W. Davis Works plant was built on the lake mainly because of the water supply. The milling process for taconite requires at least 40 tons of water for one ton of concentrate. Water for the plant is taken from the lake through a 14-ft. pipe at the rate of 105,000 gallons a minute, day and night.

Taconite processing also requires considerable electricity, about 85 k.w.h. per ton of pellets. Reserve has a 40,000-kw. steam-driven turbine generator in its power plant at Silver Bay. Some of the power generated there goes to Babbitt. The plant burns pulverized coal blown into six burners. Additional electric power required is purchased by the company.

The building of the 47-mile railroad was more than an ordinary chore. The site was surveyed in 1949. The line crosses a wilderness from moose country to the lake. It has bridges over four rivers, crosses a public road, another railroad, and has 13,600 lin. ft. of culverts from 24 to 84 in. in diameter.

Several muskeg swamps had to be mucked out. They ranged in size up to 27 ft. deep and about 3,000 ft. long.

CONCENTRATOR BUILDING: This quarter-mile-long building houses 12 processing sections, with each section comprising two storage bins; one rod mill; two magnetic cobbers; two ball mills; eight rougher magnetic separators; two rough hydro-separators; six finisher magnetic separators; two finisher hydro-separators; and one filter.



ROD MILLS: After processing through the fine-crushing plant to ¾-in. size, the material is conveyed into rod mills, where water is added, and the ore is ground into particles about the size of coarse sand.

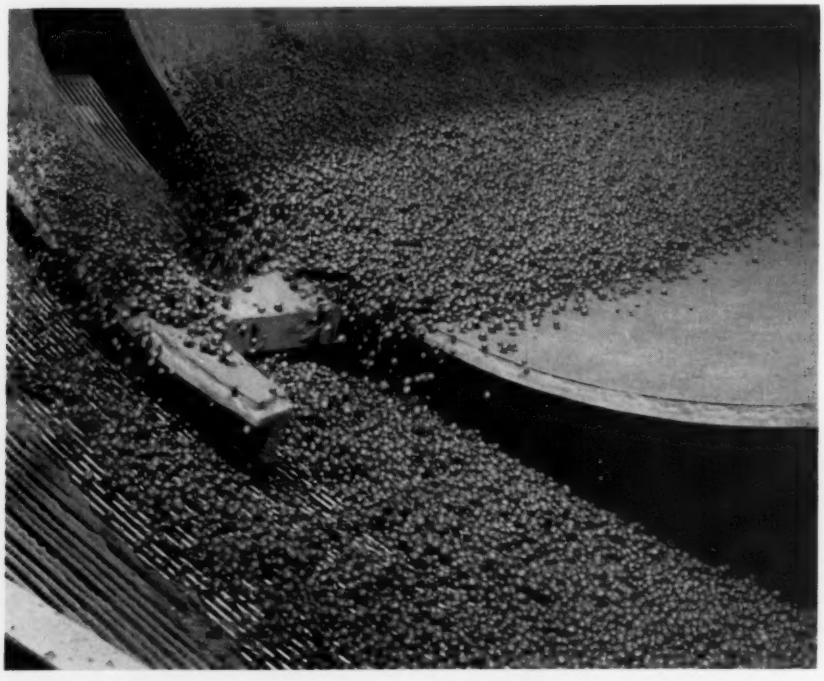
Construction of the line required 2,000,000 cu. yd. of roadway excavation. The road climbs from 867 ft. above sea level at Silver Bay to 927 ft. in the first 17 miles; then it drops 188 ft. to the Babbitt end. The maximum grade for loaded trains eastbound is 0.5 per cent. For empty traffic westbound, the maximum grade is 1.5 per cent. The railroad shops, along with the machine shop, truck shop, fabricating shop, warehouse, and electric shops, are maintained at Babbitt.

Incidentally, Reserve's railroad doesn't haul the pellets turned out at the Babbitt plant; they are transported by another railroad to Two Harbors, where they are loaded into ore boats.

Sparkling Mining Camps

When Reserve decided to launch this mammoth undertaking, the company had no workmen. There were no housing or eating facilities in the vicinity of the mine, or at the plant site on Lake Superior. Likewise, there was little hope of getting and holding efficient workmen unless the men had comfortable quarters for their families. So Reserve simply built a couple of modern, clean, attractive villages. Babbitt and Silver Bay are about the most sparkling mining camps ever seen in Minnesota, or anywhere else. When you start building a town, you have to think of a lot of things, for such a project snowballs. For example, there had to be schools and teachers, fire departments, police protection, sewage lines, retail stores, eating places, barbershops, doctors, emergency hospital facilities. Nearly all towns in this nation started as trading posts, stores, or as clusters of little businesses. Babbitt and Silver Bay sprung up all at once.

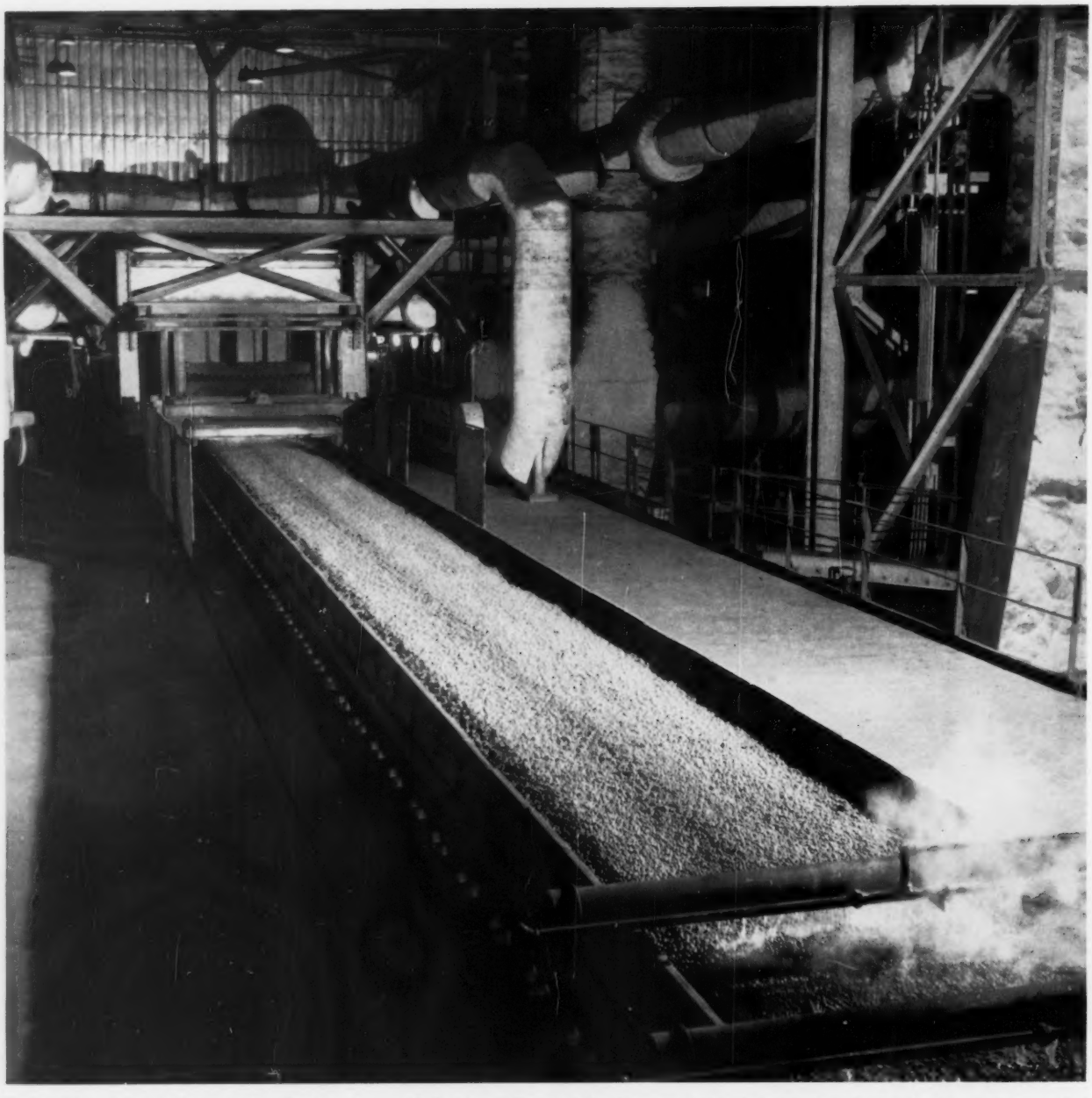
MAGNETIC SEPARATION: The final magnetic separation is carried out by the 72 finisher magnetic separators at right. At left is the filter that removes water from the concentrate which contains about 64 per cent iron ore.



ROTATING DRUMS: Like rolling a snowball down a hill, the concentrate is rolled in these rotating drums into small balls. The balls are rolled in finely ground anthracite coal before being sent to the pelletizing furnaces.

Silver Bay, which houses the personnel at the processing plant and their families, is already on the way to becoming the largest municipality on the north shore of Lake Superior with the exception of Duluth. More than 1,000 men are employed at the plant. Since many of the workmen have families, the population of Silver Bay is about 3,500. When Reserve moved in, the population was less than one person per square mile.

There's at least one interesting sta-



PELLETIZING FURNACE: The pelletizing furnace bakes the pellets at 2400 degrees F. They lie on grates about 1 ft. deep and are cooled gradually before being quenched in water and sent to the stockpile or loading bins.

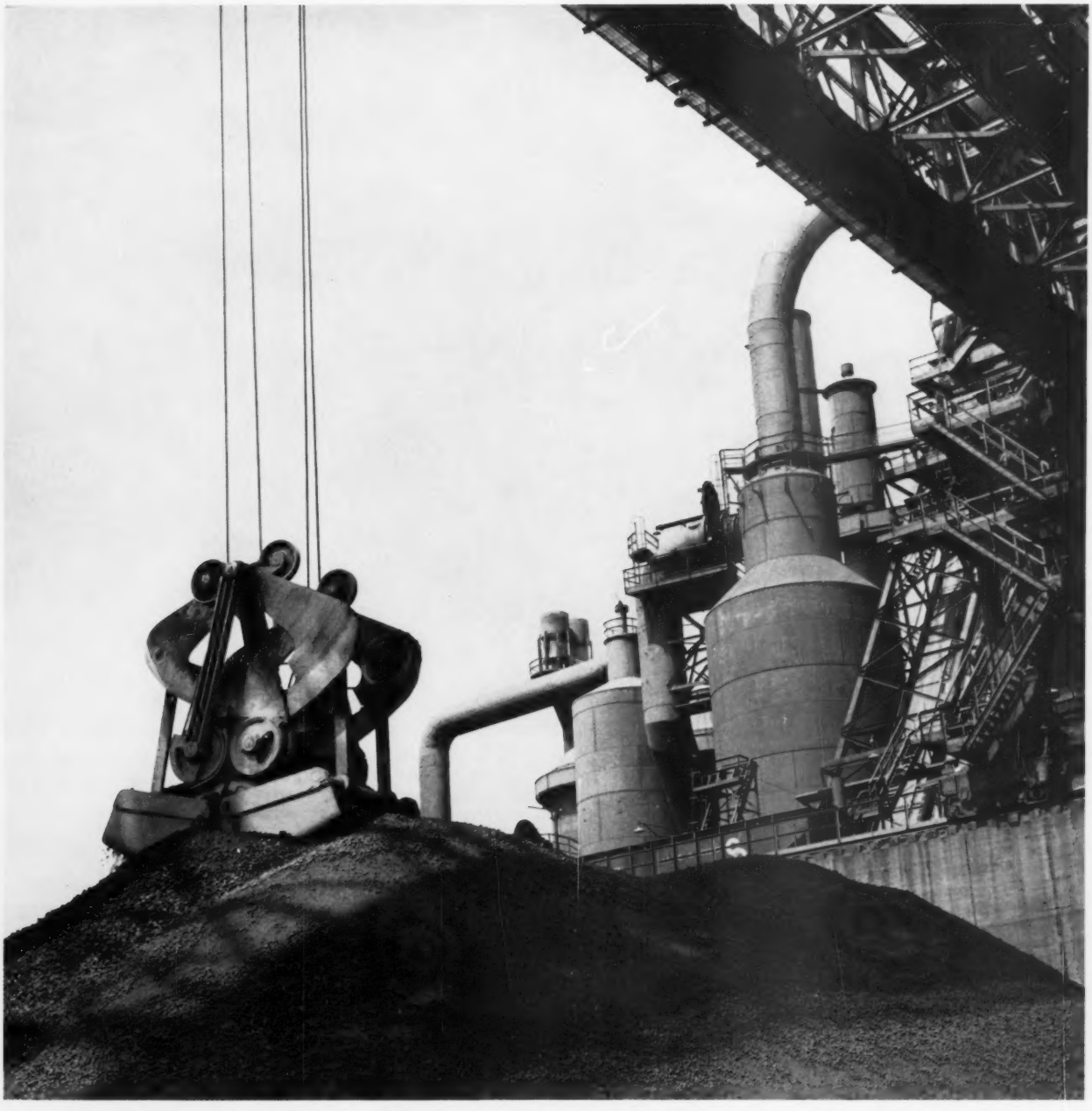
tistic about the people who live at Silver Bay and Babbitt: they have pretty good-sized families. While the national average for a family is 3.3, the average at Silver Bay and Babbitt is 4.5.

In area, Babbitt is about the largest village in the nation. It comprises the entire township of Argo – 108 sq. mi. The size was necessary to embrace Reserve's mine, crushing and loading facilities, railroad yards, and other plant property, to enable the village to qualify for a larger share of the special taconite production tax.

No shanties went up in the two towns – only modern, attractive, and comfortable houses. The street pattern at Babbitt is a loop system, which keeps heavy and fast traffic off residential streets and streets leading to schools. The company has done a lot of sodding, tree planting, and other surface beautification. The towns have had no traffic problems, no juvenile delinquency, and very little crime. They are so new that they have no cemeteries. The bodies of persons who died were returned to family hometowns. Fully 95 per cent of the workers at both Babbitt and Silver Bay came from Minnesota.

Employes Are Home Owners

Although Reserve spent about $30,000,000 in building "country club-



THE END PRODUCT: Pellets like these, the end product of Reserve's mining and milling operations, are ready for shipment to the blast furnaces of Republic Steel and Armco Steel. The annual rated capacity of the Davis Works is 3,750,000 tons of pellets.

type" mining camps, it wanted no part of a company town or a commissary system. Therefore, it is getting rid of ownership and management of the towns — selling houses to occupants and turning over municipal management and operation to the people themselves. The company will throw in such things as fire departments and sanitary systems; it will also pay most of the taxes. The majority of the homes in both Babbitt and Silver Bay, which already have incorporated and elected city officials, have been sold at prices representing losses to the company and easy-payment terms for the purchasers. Before long, Reserve will be out of the town business. Most of its employes are already home owners.

John W. Galbreath & Company of Columbus, Ohio, was employed to build and develop both towns, including the planning and the supervision of the construction of the residences, community buildings, and shopping centers. Galbreath also handles the rentals and sale of homes.

McGraw Construction Company of Middletown, Ohio, was contractor for the construction of the Babbitt plant.

Hunkin - Arundel - Dixon handled construction of the E. W. Davis Works at Silver Bay. This was a joint-venture

AN AERIAL VIEW: This picture provides an excellent overall view of Reserve's taconite-processing project at Silver Bay, Minnesota. In the foreground are pellet stockpile areas and storage bins, with an ore carrier moving into loading position. The harbor in the foreground required the dredging of 164,000 cu. yd. of variable material from the lake bottom.

W. M. Kelley, president.

R. J. Linney, vice president.

J. W. Bryant, vice president.

contract comprising Hunkin-Conkey Construction Company of Cleveland, Arundel Corporation of Baltimore, and L. E. Dixon Company of San Gabriel, California.

Reserve Mining Company's administrative offices are at Silver Bay. W. M. Kelley is president and executive head of the company. He retired as vice president in charge of operations of Republic Steel Corporation to take over the job of directing Reserve's construction program and bringing the mine and plants into production. R. J. Linney and J. W. Bryant are vice presidents. F. W. Erickson is manager of operations of Babbitt Division, and E. C. Lampman, manager of operations of the Silver Bay Division.

Deposits of taconite in the Great Lakes Region are tremendous. Reserve has at least 1,500,000,000 tons that are not being touched. While the present mine is under a slight, easy-to-move burden of glacial deposits, the additional reserve is under hard rock overburden, since the taconite deposit dips deeply. It will take quite a lot of doing to strip off the overburden covering the rocks and to mine this additional reserve. But, very likely the time will come when it will be needed, just as the time has come when taconite must be mined and milled in order to keep up our huge steel production.

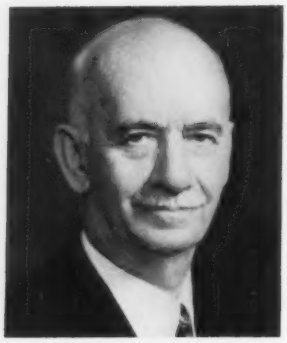
One day this past fall, a big blast of well-placed explosives was fired in the taconite. As excavation proceeded, it neared a famous hole in the ground, measuring about 5 ft. square and 6 ft. deep. The hole had been chipped out back in 1871 by Peter Mitchell, an early prospector. He was making the first systematic search for iron ore on the Mesabi Range and was traveling the old Syndicate Trail from Knife River to Lake Vermilion. His dip needle and compass behaved erratically. Mitchell figured that he may have come upon a rich deposit of iron ore. So he chipped out the test pit, quite an undertaking with the equipment available to a prospector of 1871. He found only taconite. It held little promise for him and he moved on, never dreaming that, 85 years later, the rock he rejected would become part of a mammoth muck pile of taconite in the Reserve mine.

BEAUTIFUL NEW TOWN: The new and beautiful town of Silver Bay in the north woods of Lake Superior has more than 700 homes, a shopping center, an elementary school, churches, and a community center. Designed by community-planning experts, it is modern in every way.

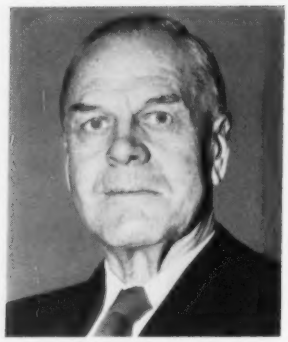
F. W. Erickson, manager of operations, Babbitt Division.

E. C. Lampman, manager of operations, Silver Bay Division.

W. J. ROHAN



W. E. KIER



O. W. PETERSON

A. H. AYERS

THE BEAVERS
HONOR ELEVEN MEN

The Beavers, a social organization of men prominent in the heavy-engineered construction industry west of the Mississippi, attended the second annual Golden Awards dinner of the organization on January 17 at the Biltmore Hotel in Los Angeles. The highlight of the dinner was the presentation of the Beavers Golden Awards to eleven men who have contributed meritorious service to the industry. The recipients of the awards were:

MANAGEMENT: W. J. Rohan, Winston Brothers Company; and W. E. Kier, W. E. Kier Construction Company.

ENGINEERING: O. W. Peterson, Pacific Gas and Electric Company; and A. H. Ayers, consulting engineer.

SUPERVISION: Ben Arp, Utah Construction Company; and E. M. Whipple, Bechtel Company.

SUPPLY: A. J. Gock, Bank of America; and A. F. Garlinghouse, Garlinghouse Brothers.

SPECIAL: S. D. Sturgis, Jr., lieutenant general, former chief of Engineers, U. S. Army; R. B. Diemer, Metropolitan Water District of Southern California; and W. A. Johnson, American Pipe and Construction Company. The W. A. Johnson award was made posthumously. It was accepted by Mrs. W. R. Fuller and Mrs. E. G. Corkett.

BEN ARP

E. M. WHIPPLE

A. F. GARLINGHOUSE

A. J. GOCK

W. A. JOHNSON

LIEUT. GEN. S. D. STURGIS, JR.

R. B. DIEMER

The Use of Short-Period Delay Electric Blasting Caps in Underground Clay Mines

This article is a reprint of a manuscript prepared by A. Perry Mason and read by him to members and associates of The Refractories Institute of Pittsburgh, Pennsylvania, at the 1956 Annual Award Contest of the Institute in Point Clear, Alabama, on May 11, 1956. Mr. Mason was awarded the first prize, a certificate and a $100 defense bond.

THE blasting operation is vitally important in underground clay mining. Breakage, fragmentation, and throw are factors which affect the loading and crushing of the clay considerably. Another important factor in some areas is the roof condition.

A desire to control these factors led to a series of experiments with short-period delay electric blasting caps in three of the clay mines of The McLain Fire Brick Division of H. K. Porter Company, Inc. Two of the mines are in the Lower Kittanning vein of the Allegheny series and the third is in the Tionesta vein of the Pottsville series, all being members of the Pennsylvania system. The clay beds vary from 6 to 14 ft. in thickness, and all of them are overlain by from 1 to 3 ft. of coal. All mining is done by a modified room-and-pillar method. The unstable character of the roof necessitates leaving large blocks for support, and consequently only about 50 per cent of the clay is removed from any given area.

The clay is all "shot-off-the-solid," that is, it is not cut in any manner before blasting. Rooms and entries are driven at 15 to 16-ft. widths, and the pillars vary from 40 to 100 ft. square. Points established by the survey crew are used to keep the places on line. Drilling is done by either a.c. or d.c. electric drills which are mounted on either a vertical post or a horizontal, rib-to-rib post. The clay is loaded directly into rail-mounted mine cars by a Joy loading machine.

One of the requirements of a good fire-clay is a low combustible material content. Carbonaceous materials, including coal, burn out during the firing of the brick and cause an increase in the porosity and a loss of weight. The coal roof in this area is quite weak, and it is difficult to keep it from coming down on the clay when blasting. For many years, black blasting powder was used in the top drill holes to minimize the shock on the roof, thus reducing the amount of coal that fell. However, the use of black powder was discontinued several years ago as a safety measure, because black powder is an extremely dangerous explosive to handle. Several types of slow-speed dynamites and blasting powders have been used, but none of these have been too effective in preventing the coal from falling.

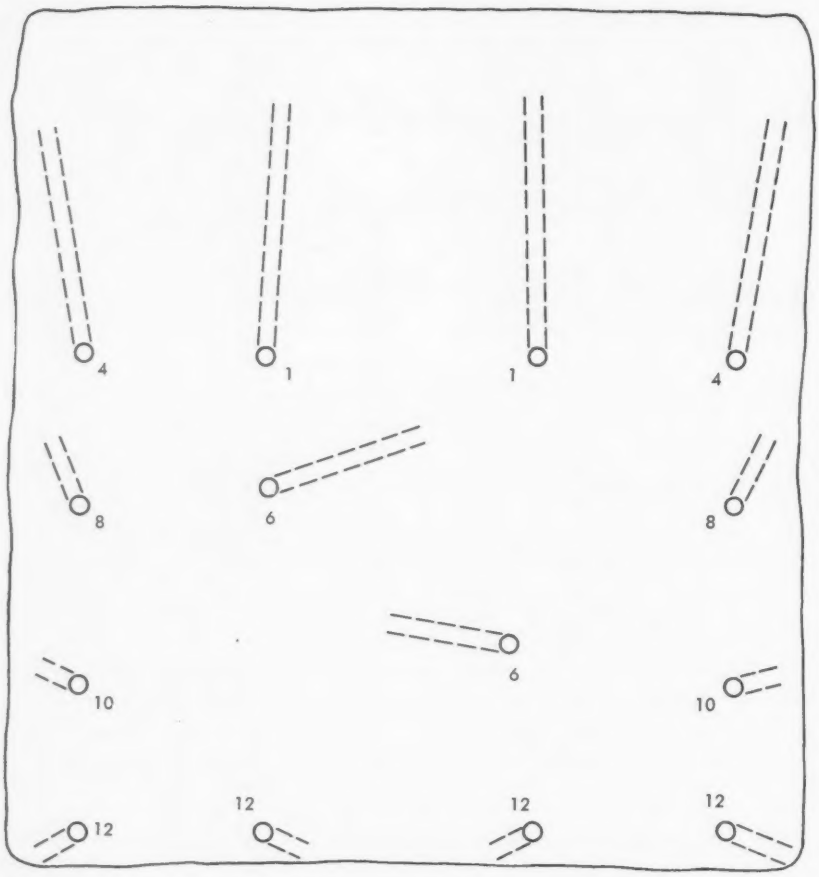
Mine No. 1

The seriousness of the contamination of the clay by coal was first realized at Mine No. 1. The amount of coal being loaded was of such magnitude as to be extremely detrimental to the brick, and kiln losses were higher than management could tolerate. Laborers were used in the mine to pick the coal from the clay, but they were not able to remove enough of the coal to make sufficient improvement in the burned brick. All of the visible coal was picked out, but large amounts were found mixed in the pile, evidently having been shaken from the roof with the initial firing and covered by the detonation of succeeding holes.

The detonators used to fire the charges were regular blasting caps with fuse igniters. The time interval between the firing of the holes in any one face was controlled by the length of fuse and the order of lighting. A single face might require 10 to 15 seconds to be completely blasted. The time lag between the firing of succeeding holes meant that every detonation served to set up a shock wave in the room and the roof was subject to a series of independent vibrations. This caused the coal to shatter and fall. The use of short-period delay electric blasting caps was suggested as a means of eliminating or at least reducing this problem.

Hercules® Short-Period Delays are similar to the regular blasting caps, but are fired with electricity. Each cap is equipped with two leg wires, connected in the cap by a bridge of high-resistance material that heats to ignite the explosive charge within the cap when an electric current is applied. The entire series consists of 16 caps numbered from 1 to 16 consecutively, and each number designates a slightly longer delay in detonation. The time required to fire a complete series is approximately 0.6 of a second. No complete series of 16 caps was used by the company. In each case, the best results were obtained by using a combination such as 1-4-6-8-10-12-14-16, or some similar series.

The short-period delay cap is placed lengthwise in a cartridge of dynamite and loaded near the back of the drill hole (never at the end of the hole). The "business end" of the cap is directed outwardly – toward the bulk of



IN MINE NO. 1: This represents a 14-hole round of blast holes drilled into a face 10 to 12 ft. high and 15 ft. wide in Mine No. 1. The figures near the holes represent the delay periods of the short-period delay electric blasting caps used to detonate the dynamite charges. The introduction of short-period delay caps reduced the amount of explosives loaded by one-third.

the explosive. Leg wires are held taut during loading to prevent breaking. After all holes are loaded, the leg wires are connected in series. A galvanometer is used to check the face circuit, and if it is all right, the lead-out wires are shunted, leaving a closed circuit that cannot be detonated by stray currents. The shot-firing cable is strung back from near the face to a safe place from which the shot can be fired. The wires in the cable are connected to the face only when ready to blast. The galvanometer is again used to check the circuit, and if it is satisfactory, the blasting machine is connected and the blast fired. If a continuous circuit is not indicated, or if higher than normal current is indicated, an attempt to find the short-circuit is made. If a broken wire is found, it is of course repaired or replaced.

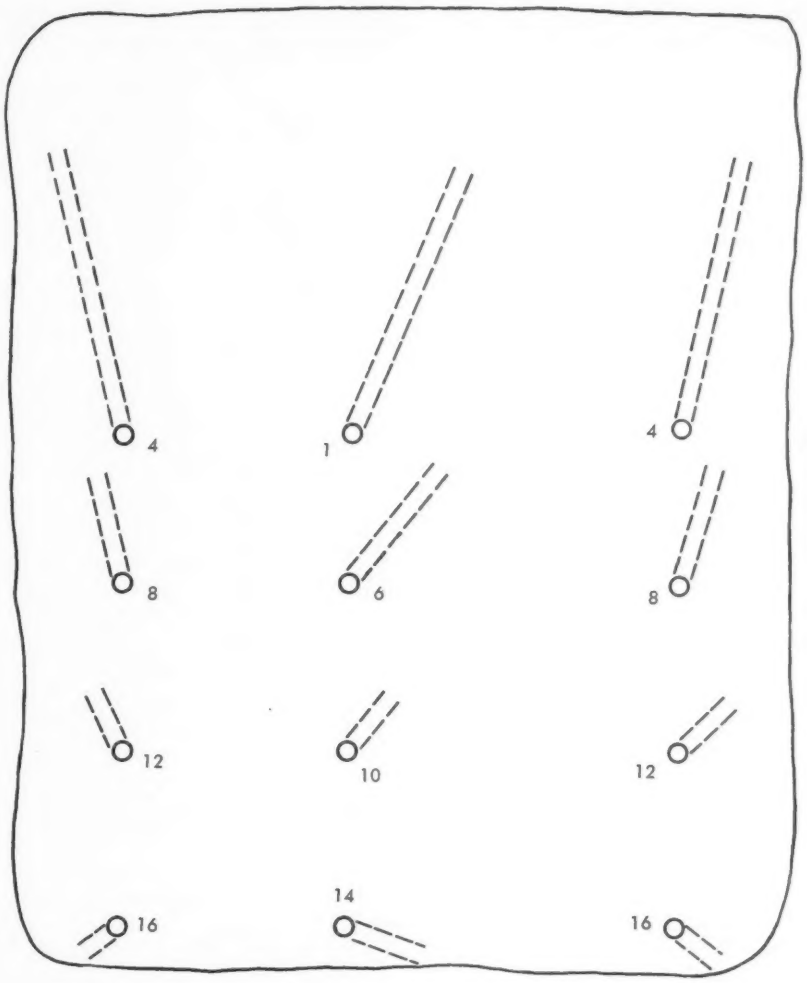
If a defective cap is indicated, it must be taken out of the series, and after blasting the place it is treated as a misfire in a manner prescribed by law. One, two, or three rooms may be connected in series and fired simultaneously if they are fairly close together. Variations in galvanometer readings will be caused by changing the number of caps and length of firing cable.

The changeover from regular caps to short-period delay caps in Mine No. 1 was made with the aid of a technical representative of the powder company. The first blast made with short-period delays revealed that a decrease in the amount of powder used in each hole was necessary. The clay was thrown over 100 ft. back from the face, as opposed to a throw of about 30 ft. experienced with the regular caps. The extreme throw made loading very difficult, requiring more than double the amount of tramming with the loading machine. Fragmentation was increased, indicating that much of the explosive charge had been expended in needlessly pulverizing the clay. An immediate appraisal of the effect on the coal was impossible, as it was thought that the effects of the previous blast (made with regular caps) coupled with the apparent use of too much dynamite would cause more coal to fall. It was noted, however, that all coal that came down was on top of the pile and could be picked off.

The use of short-period delay caps was continued, and the amount of explosives used was gradually reduced to the minimum amount required to pull the blast. The reduction in powder was nearly one-third of the original amount used. The saving in powder was enough to compensate for the increased cost of short-period delay caps. In addition, the overall effect of the roof was beneficial. The coal came with some blasts, but in smaller quantities. The throw was still more than desired, being about 50 ft. This made loading somewhat more difficult, but not enough to seriously decrease daily output. Fragmentation was excellent. The loading machine was able to stay at the pile rather than be pulled back while large pieces were broken with picks and sledges as had been required previously. The pile was less compacted and this, too, made loading easier. Having weighed the merits of the short-period delay caps against regular caps, it was decided to make the changeover permanent.

The short-period delay caps not only gave the benefits herein mentioned, but more important, they added immeasurably to the safety of the blasting operation. The fact that the blaster can detonate a blast from a place of safety completely removed from the blast area is a valuable asset. The blaster using regular caps with fuse must light the fuses at the face and there is the ever-present danger of having cut a fuse too short, or encountering difficulty in lighting a fuse after some have been ignited, or more commonly, misjudging the burning rate of the fuse. Accidents from such causes are not too frequent, but they have occurred often enough to be considered major factors in comparing the two methods.

IN MINE NO. 2: This is a diagram of a 12-hole round of blast holes drilled into a face 12 to 15 ft. high and 14 ft. wide in Mine No. 2. The figures indicate the location of the short-period delay electric blasting caps used to detonate the explosives in the respective holes. Blasts yielded longer, lower piles of fine clay with few large pieces.



Mine No. 2

The blasting problems at the No. 2 Mine were similar to those that had been encountered at the No. 1 Mine. In addition to the roof control and breakage problem, there were two other matters that required consideration. First, the roof had to be timbered continuously (three-member sets are used, one being horizontal – the cap, and the two others vertical – the posts) and some timber sets were less than 4 ft. from the face before it was blasted. Frequently, the timbers were knocked over or askew. As a result, coal often fell on the pile, and the timbers had to be reset. Secondly, the bottom row of holes did not pull well; bootlegs (back parts of the hole that were not broken by the explosives) of 2 or 3 ft. were not uncommon. This caused a great deal of trouble in loading the clay, and also in drilling the face. Partially broken rock causes deflection of the drill bit with consequent bending and binding of the drill steel.

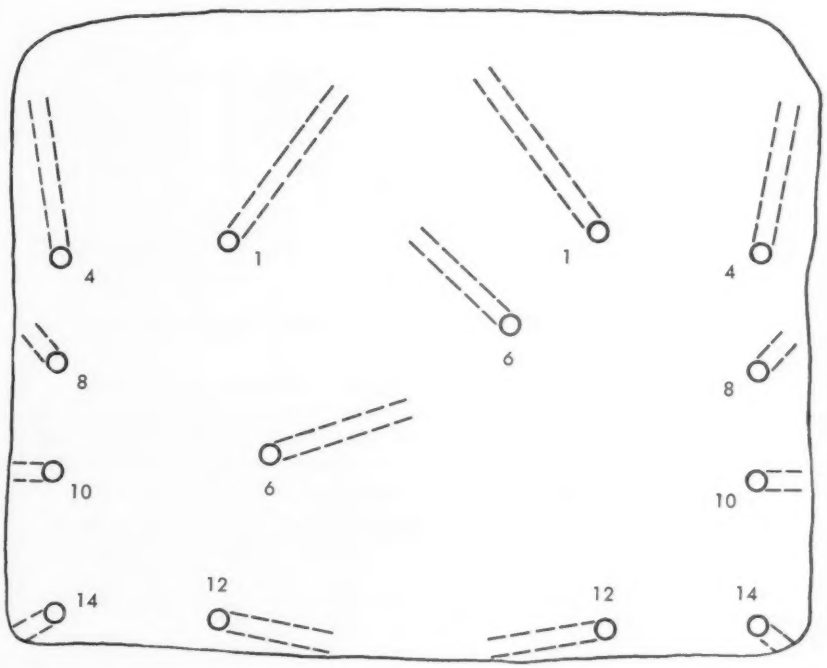
Short-period delay caps were adopted after making several trial blasts. The following observations were made after 13 blasts had been made:

The amount of powder has been gradually reduced until consumption is about 25 per cent less than required with cap-and-fuse blasting.

All blasts yielded a pile of fine clay with very few large pieces. Blasted clay was thrown about 40 ft., giving a longer, lower, but less compact pile which is handled by the Joy loader with ease.

Less coal came down with the blasts.

All coal that fell was on top of the pile and could be picked off.



IN MINE NO. 3: This shows a 14-hole round of blast holes drilled into a face 7 to 9 ft. high and 16 ft. wide in Mine No. 3. The figures alongside the holes show the delay periods of the blasting caps used to detonate the dynamite charges in the round.

Damage to the timber was materially reduced, and none of the bents of timber were completely knocked out. The roof conditions appear to be more favorable in general.

The continued use of short-period delay electric blasting caps has confirmed these observations.

Mine No. 3

A study of the blasting procedure and results at the No. 3 Mine was made as a result of the experience at No. 1 and No. 2 Mines. Similar problems involving the coal and coal-clay mixtures in the piles were noted. Also, the amount of clay removed with each shot was less than the company thought it should be. Bootlegs of 20 to 30 in. were the rule rather than the exception. The drill holes were all 6 ft. long, but the average blast pulled only about 4 ft. of clay. In the No. 2 section where rooms 6 ft. in height were being driven, large pieces of clay on the Joy loader boom struck the roof and were doubtless adding to the bad roof condition.

Short-period delay caps yielded better results in fragmentation, particularly notable in the No. 2 section. Damage to the coal was lessened, and the mixing of coal throughout the clay was eliminated. The amount of bootleg was reduced by 6 or 8 in. After familiarizing the drilling and blasting crews with the short-period delay caps, an attempt was made to increase the amount of clay from each blast. Drillhole length was increased to 8 ft. in all rooms that were 8 or more ft. high. The amount of dynamite used in each hole was not changed, but the volume of clay that was blasted increased. This was an indication that much of the explosive charge had been wasted in the 6-ft. holes previously used. The average bootleg was still about 18 in. however, and this was undesirable and expensive. A change in the size of dynamite cartridge was tried and it gave the desired results. The 1¼-diameter by 8-in.-long cartridges were replaced by 1¾ by 8-in. cartridges. The larger cartridges contained twice as much dynamite, and only half as many cartridges were used in each hole. Bootlegs were cut to about 6 in., and the combination of changes nearly doubled the size of the clay piles.

One of the lessons derived from the adoption of short-period delay electric blasting caps was that an occasional review of the entire blasting operation at each mine should be made. The arguments in favor of delay caps have been to the satisfaction of The McLain Fire Brick Division, H. K. Porter Company, Inc. The added safety at no extra cost, together with the absence of misfires and their attendant problems, is of enough import in its own right to justify the change.

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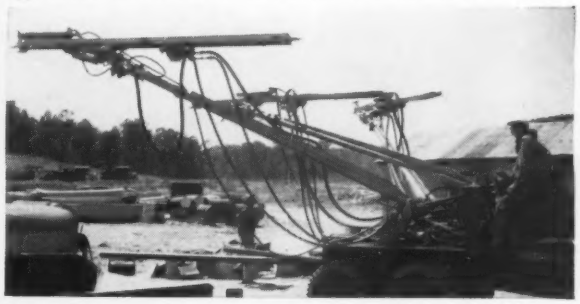

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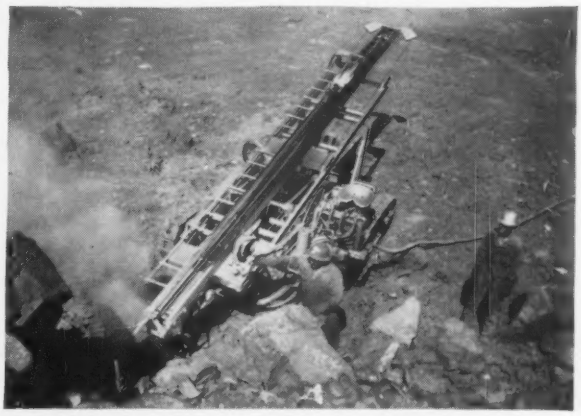

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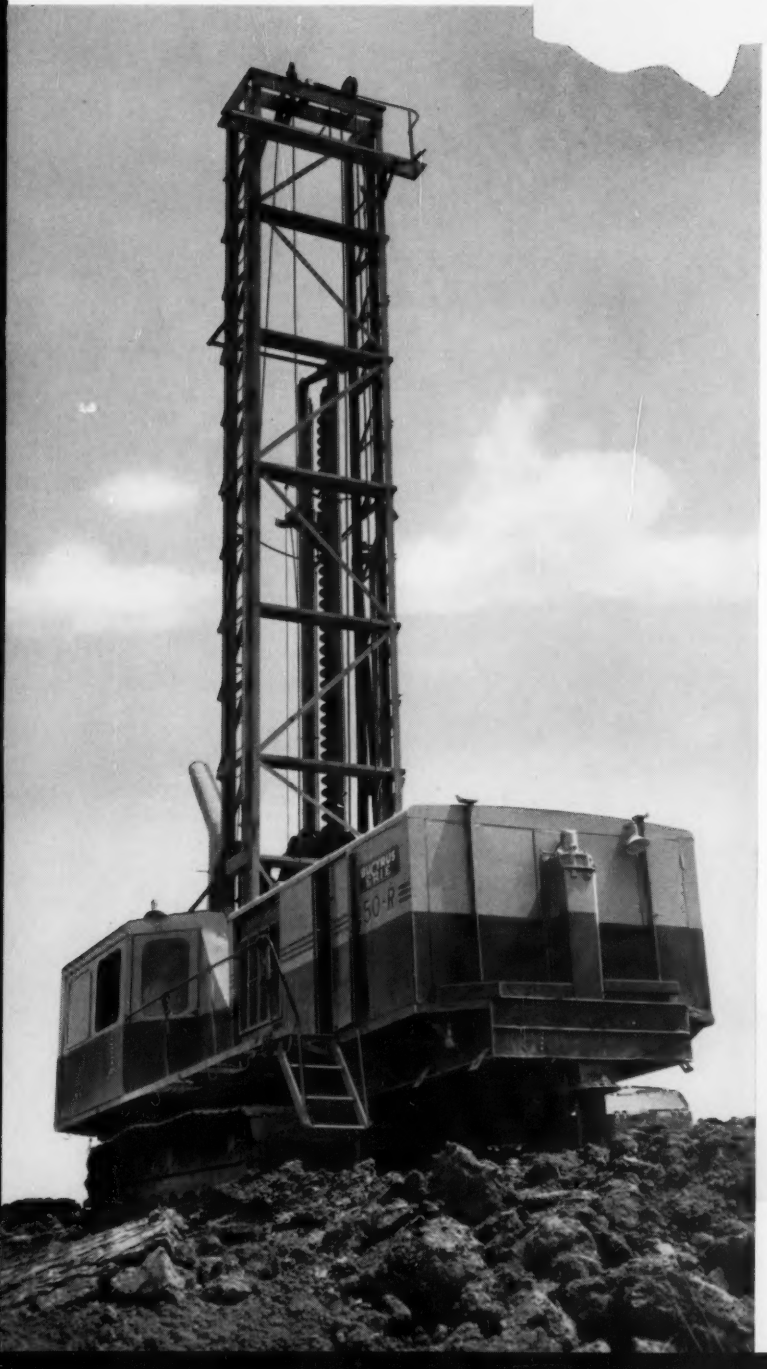

At the Central Ohio Coal Company mine, this 50-R drilling 10⅝-in. holes through mixed overburden put down an average of 95 feet per shift hour during a period covering 20 shifts. Figuring actual drilling time at 80%, this was an average penetration of 118½ feet per drilling hour. The overburden consisted of approximately 35% clay, 25% sandstone, 35% shale, and 5% limestone with occasional fireclay over the coal seam.

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The knot shown is the clove hitch made in the Plain Primacord trunk line and drawn tightly around the twin branch lines.

P-1